

## Conference Paper

# The theoretical Significance of Amphibian Anomalies from the Standpoint of the Module Principle

V.L. Vershinin<sup>1,2</sup>

<sup>1</sup>Institute of Plant and Animal Ecology, Ural Branch of Russian Academy of Sciences, 8 Marta 202, 620144 Yekaterinburg, Russia

<sup>2</sup>Ural Federal University, Mira 19, 620002 Yekaterinburg, Russia

## Abstract

The morphological deviations of amphibians are analyzed from the standpoint of the module principle of biological systems and mechanisms of evolution. This predetermines the similarity of evolutionary changes in different groups and limits the number of possible ways for evolutionary development. The populations of eight Uralian species of amphibians are analyzed for deviation variants that are norms for other species. Also discussed are potential spectra of deviations and ecological profiling of phenotypes from the point of view an "ecological sieve". The environment plays a significant regulatory role in the diversification of ontogenesis. This is why morphological deviations can be significant pointers for discovering the reality of a population's morphogenesis.

**Keywords:** amphibian, morphological anomalies, deviations spectra, morphogenesis, evolution, ecological profiling.

Corresponding Author:

V.L. Vershinin  
vol\_de\_mar@list.ru

Received: 23 January 2018

Accepted: 20 April 2018

Published: 3 May 2018

Publishing services provided by  
Knowledge E

© V.L. Vershinin. This article is distributed under the terms of the [Creative Commons](#)

[Attribution License](#), which permits unrestricted use and redistribution provided that the original author and source are credited.

Selection and Peer-review under the responsibility of the Amphibian and Reptiles Anomalies and Pathology Conference Committee.

## 1. Introduction

Anomalies have attracted human attention for a long time. However, besides admiring the phenomena, we need an explanation for their possible reasons. The first attempts to use anomalies in ideas about the appearance of new species and the transformation of species were made by K. Linnaeus in 1744 [1], V. Goethe in 1790 [2], Etien Saint-Hilaire in 1822 [3] and Isidore Geoffroy Saint-Hilaire in 1932 [4]. They were the first to say that "anomalies is not a disorder, but a different order, subjected to the same laws". At the begining of the 20<sup>th</sup> century, scientists began to speak about internal reasons that the determine direction and forms of variability [5]. Despite external conditions, evolution moves in a particular direction due to "...internal constitutional reasons related to the chemical structure of the protoplasm" [5]. The principle of releasing latent endogenous "prescribed potentials" is to give original credit where is due,

## OPEN ACCESS

in referring to both ontogeny and phylogeny ... without room for chance". This is "widespread and caused by internal factors, the method of evolutionary transformation" [5]. At the foundation of these parallelisms is the isomorphism of living matter, i.e. similarity in the structure of the substance [6]. The base of the module principle of biological systems structure and mechanisms of evolution (which is actually aimed at the search for a periodic system in biology) was laid in 1922 by N.I. Vavilov [7]. Scientists began to understand that the chance for mutation lie within the biochemical potential of the species. Point mutations cannot provide rapid evolution: "...It's difficult to mend the clock by shooting it..." [8].

Now we have the information that "... molecular evolution is characterized by high repeatability: different organisms have independently moved in the same 'approved' evolutionary trajectories" [9]. Susumu Ohno [10] showed that in evolution hybridization, parthenogenesis and polyploidy are closely related (the idea of genome duplication). At the end of the 20<sup>th</sup> and beginning of the 21<sup>st</sup> centuries, the module principle of evolution was formed [7]: "...all existing things arose from the small number of certain covariant [here exactly not invariant but covariant] domains, which were then connected in different combinations" [11]. This is why variability is limited and similar. This predetermines the similarity of evolutionary changes in different groups and limits the possible ways of evolutionary development. Through diversification, evolution travels along the main path to morphogenesis realization [12]. In other words, the norm changes [13]. This is why the abnormal features of one species are, in some cases, the norms of others.

The main objective of our research was to analyze the real situation in amphibian populations in the Urals in terms of the distribution of deviation variants in one species that are norms for another. We also seek to determine their frequencies in natural populations and plan to revise existing information on the spectra of potentially widespread anomalies for all amphibian species in the region.

## 2. Methods

We analyzed long-term data on the external anomalies detected in amphibian populations in the urban and rural territories of the Urals from 1977 to 2015. The anomalies were detected in samples of juveniles and adults from 8 amphibian species (*Salamandrella keyserlingii*, *Lissotriton vulgaris*, *Bufo bufo*, *Bufo viridis*, *Rana temporaria*, *R. arvalis*, *R. amurensis*, *Pelophylax ridibundus* (total number under investigation – 32,071 specimens)). To identify anomaly variants, we have used the classification systems

of J. Rostand [14], A. Dubois [15], M. J. Tyler [16], V. L. Vershinin [17] and K. Henle et al. [18]. For the spectra used to evaluate possible deviations, we have used the term “potential spectrum”, by which we mean all the abnormal variants found in the region.

### 3. Results

An important feature of the spectra of morphological abnormalities are the deviant variants present as the norm in another species (Table. 1). We identified 19 such variants: 8 cases in the moor frog, 4 in the common frog, 2 for the marsh frog, 2 in the Siberian salamander and 1 in the common newt.

We revised information about the deviation spectra of eight of the amphibian species under research (Table 2). Thus for *S. keyserlingii* the presence of 13 deviant forms are currently established, for *L. vulgaris* – 13, for *B. bufo* – 7, for *B. viridis* – 4, for *R. arvalis* – 24, for *R. temporaria* – 19, for *R. amurensis* – 8 and *P. ridibundus* – 19.

TABLE 1: Frequency of abnormalities that can be norms for other species.

N	Feature	Anomaly frequency % (n)	Species	Species norm
1	Open opercular chamber	1.4 (1995)	<i>P. ridibundus</i>	<i>Leiopelma sp.</i> ,
2	Urostyle with vertebrae	4.91 (509)	<i>Rana arvalis</i>	<i>Triadobatrachus massinoti</i>
3	Urostyle with vertebrae	1.09 (275)	<i>R. temporaria</i>	<i>Triadobatrachus massinoti</i>
4	Urostyle with vertebrae	0.34 (294)	<i>P. ridibundus</i>	<i>Triadobatrachus massinoti</i>
5	Atavistic tail	0.1 (976)	<i>R. arvalis</i>	<i>Leiopelma sp.</i> , <i>Ascafus sp.</i>
6	Absence of eyelids	0.036 (5617)	<i>R. temporaria</i>	<i>Xenopus sp.</i>
7	Absence of eyelids	0.041 (17119)	<i>R. arvalis</i>	<i>Xenopus sp.</i>
8	Oligodactyly	0.071 (4859)	<i>R. temporaria</i>	<i>Psyllophryne hermogenesi</i>
9	Brachycephaly	0.047 (17119)	<i>R. arvalis</i>	<i>Breviceps mossambicus</i>
10	Brachymely	0.07 (1995)	<i>P. ridibundus</i>	<i>Breviceps adspersus</i>
11	Brachymely	0.13 (17119)	<i>R. arvalis</i>	<i>Breviceps adspersus</i>
12	Ectro- oligo- syndactyly	7.3 (1247)	<i>S. keyserlingii</i>	<i>Bolitoglossa dofleini</i>
13	Hind limbs absence	0.0058 (17119)	<i>R. arvalis</i>	<i>Siren lacertina</i>
14	Polydactyly	0.056 (1247)	<i>S. keyserlingii</i>	<i>Ichthyostega sp</i>
15	Polydactyly	0.023 (17119)	<i>R. arvalis</i>	<i>Acanthostega gunnari</i>
16	Macrophtalmy with brachycephaly	1.49 (134)	<i>R. amurensis</i>	<i>Bufo lemur</i>
17	Macrophtalmy with brachycephaly	0.005 (17119)	<i>R. arvalis</i>	<i>Bufo lemur</i>
18	Ceratobranchialia	0.42 (981)	<i>L. vulgaris</i>	<i>Brachyciormus noachicus</i>
19	Depigmented ventral skin	0.27 (5617)	<i>R. temporaria</i>	Centrolenidae

TABLE 2: Spectra of external morphological anomalies.

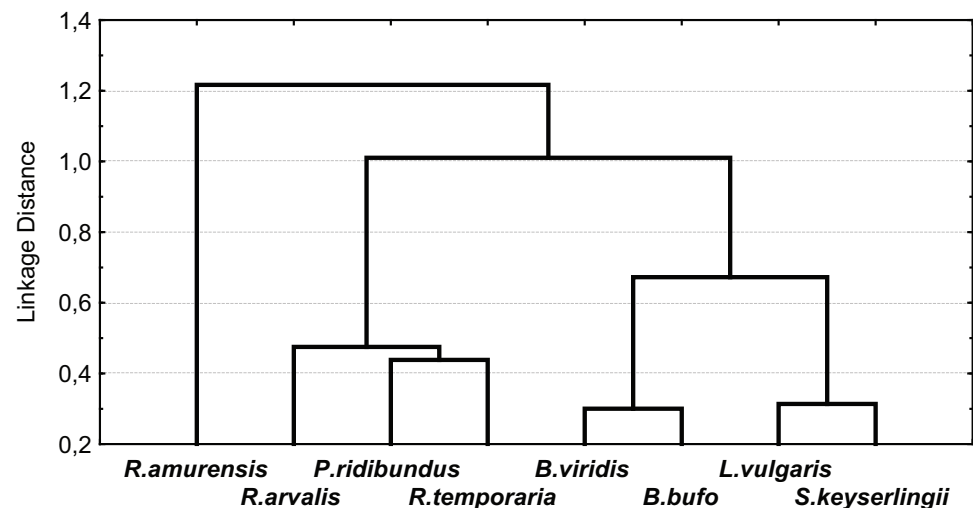
Variants	S.k	L.v	B.b	B.v	R.t	R.a	P.r	R.am
Brachycephaly	–	–	–	–	–	+	–	+
Microphthalmia	+	–	–	–	+	+	+	+
Macrophthalmia	–	–	–	–	–	+	–	+
Lack of eyelids	–	–	–	–	+	+	–	–
Blackeye	–	–	+	–	+	+	+	–
Eye deformities	+	+	+	–	+	+	+	–
Mandibular hypoplasia	–	–	–	–	–	+	–	–
Oedema	+	+	–	–	+	+	+	–
Axial deformities	+	+	+	–	+	+	+	–
Opercular chamber anomaly	–	–	–	–	–	+	+	–
Ceratobranchiale	+	–	–	–	–	–	–	–
Dissipation of melanin	–	–	–	–	+	+	+	–
Pigmentation anomaly	+	+	–	–	+	+	+	+
Arthrogryposis	–	–	–	–	+	+	+	–
Hemimely	–	–	–	–	+	+	+	+
Brachimely	+	+	+	+	+	+	+	–
Ectromely	+	+	–	–	+	+	+	+
Taumely	+	+	–	–	+	+	+	–
Polymely	+	–	–	–	+	+	+	–
Ectrodactyly	+	+	+	+	+	+	+	+
Syndactyly	+	+	+	+	+	+	–	+
Oligodactyly	+	+	–	–	–	+	+	–
Shizodactyly	+	+	+	+	+	+	+	–
Polydactyly	+	+	–	–	+	+	+	–
Internal defects	–	–	–	–	+	+	+	–
Neoplasm	–	+	–	–	–	–	–	–

(Notes: + - the presence of anomaly, – - absence; S. k - *S. keyserlingii*, L. v - *L. vulgaris*, B. b. - *B. bufo*, B.v. - *B. viridis*, R. t - *R. temporaria*, R. a - *R. arvalis*, P. r - *P. ridibundus*, R. am - *R. amurensis*).

The distancing of the quality spectra (Fig. 1) is related to taxonomic position and the volume of information on concrete species (the number of analyzed specimens).

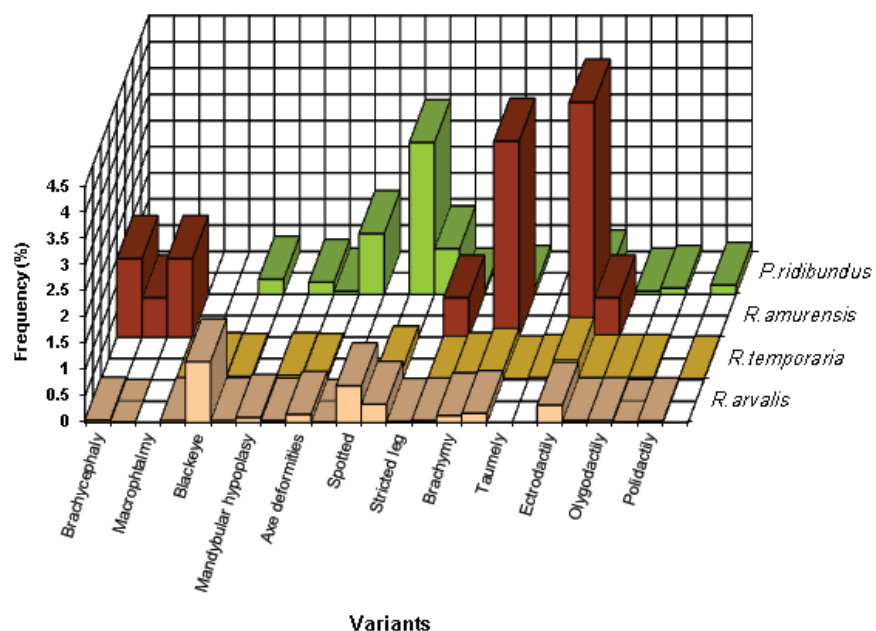
Morphogenesis diversification under effect of the same environmental conditions can be differ in different families of the same order. For example, take the frequency of oligomerization variants in juvenile and adult *S. keyserlingii* and the frequency of polymerization variants in *L. vulgaris* under the effect of urbanization [19].

A comparison of the anomaly spectra in juveniles from the 4 Ranidae family species under investigation shows that the morphogenetic diversification of related species



**Figure 1:** Distances of the interspecies anomalies spectra (complete linkage, Pearson's -r).

differs. The morphology of the new generation can be profiled in terms of environment, but the profile is unique for any one species (Figure 2).



**Figure 2:** Specific "gates" in phenotype realization for juveniles of the investigated Ranidae species ("ecological sieve").

We also found that urban environmental fragmentation leads to an increase in the frequency of iris depigmentation, mandibular hypoplasia and dissipation of the skin melanin rate, along with urbanization degree. However, the former is not limited by a natural physical border (River Iset). So, the geographical distribution of anomalies and

their frequencies are related to some natural barriers, factors and gradients, as well as anthropogenic environmental transformation and the extent of pollution.

It is evident that ecological mechanisms play a significant role in ontogenesis and phylogenesis. Morphogenesis is ruled by the interaction of the genetic base and epigenetic regulators in accordance with the reaction-diffusion model of A. Turing [20], where the environment plays the role of a mediator. This is why the same phenotypes can be determined by different interacting (synergetic) factors. Similar deviations in morphology can be induced for different reasons: microphthalmia can be related to a mutation in one of the forms of beta-integrin [21] and changes the function of heat shock protein 90 [22]. Parasites can also induce an increase in the number of skeletal deviations thanks to synergetic effects [23].

Ecological mechanisms play a significant role in the diversification of morphogenesis pathways. This is why a definitive phenotype is not computable only through its initial parameters: it is an integrative result of the complicated interaction of existing internal and external factors that works as a base for profiling the most adaptive and functionally perfect form in particular environmental conditions. Our knowledge on the genetic determination of morphological specifics is developing towards the ecological epigenetic regulation of phenotypes: morphological deviations can be significant indicators for discovering the reality of a population's morphogenesis.

## 4. Conclusion

1. Morphogenesis is carried out in accordance with the module principle of the organization of biological systems.
2. Variability is initially limited and definitely vectored by the molecular basis of each of the signs, the infragenomic interaction unity of the functional organization of the latent potentiality and epigenetic regulation.
3. Phenotypic variability is profiled by the expression of morphogenesis regulators under environmental conditions and the state of co-evolutionary systems.
4. The potential range of deviations contains information on the evolutionary potential of the taxon and its adaptive capacity.

... Terats are not "promising monsters", but rather the "distorting mirror of evolution".

## Acknowledgments

The work was performed within the frameworks of state contract with the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, and partly supported by Complex program of UBRAS (project № 18-4-4-28) and by Act 211, Government of the Russian Federation, contract № 02.A03.21.0006.

## References

- [1] Gustafsson A: Linnaeus' Peloria: The History of a Monster. *Theor. Appl. Genet.* 1979. (54): 241-248.
- [2] Goethe JW: Versuch die Metamorphose der Pflanzen zu erklären. Gotha: C.W. Ettinger, 1790.
- [3] Geoffroy Saint-Hilaire E: Philosophie anatomique. II. Paris, 1822.
- [4] Geoffroy Saint-Hilaire I: Histoire generale et particuliere des anomalies de l'organisation chez l'homme et les animaux, ouvrage comprenant des recherches sur les caracteres, la classification, l'influence physiologique et pathologique, les rapports generaux, les lois et les causes des monstruosites, des varietes et des vices de conformation, ou traite de teratologie. Tome premier. Paris: Bailliere, 1832.
- [5] Berg L: Nomogenesis; or, Evolution Determined by Law. London, Constable, 1926.
- [6] Sobolew D: Über Clymenien Und Goniatiten. *Paleontologische Zeitschrift.* 1914. 1: 348-378.
- [7] Vavilov NI: The law of homologous series in variation. *J. Genet.* 1922. (12), 1: 47-89.
- [8] Timofeeff-Ressovsky NW, Yaablokov AV and Glotov NV: Grundriss der Populationslehre. Jena: Gustav Fischer Verlag, 1977.
- [9] Weinreich DM, Delaney NF, DePristo MA, Hartl DL: Darwinian Evolution Can Follow Only Very Few Mutational Paths to Fitter Proteins. *Science.* 2006. 312: 111-114.
- [10] Ohno S: Evolution by gene duplication. Springer - Verlag; New York, 1970.
- [11] Inge-Vechtomov SG: A Possible Role of Translation Ambiguity in Gene Evolution (A Hypothesis). *Molecular Biology.* 2002. (36), 2: 202-208.
- [12] Shishkin MA: Evolution as epigenetic process. In: Modern paleontology. Methods, directions, practical addition: Handbook manual in 2 volumes. Ed. Menner VV. Makridin VP. Moscow: Nedra, 1988. 2: 142-169 [in Russian].
- [13] Kovalenko EE: Feature norm effect and its theoretic significance. *Evolutionary biology: history and theory.* 2003. 2: 66-87 [in Russian].

- [14] Rostand J: Les anomalies des amphibiens anoures. Sedes, Paris, 1958.
- [15] Dubois A: Anomalies and mutations in natural populations of the *Rana "esculenta"* complex (Amphibia, Anura). Mitt. zool. Mus. Berlin. 1979. (1.1), 55: 59-87.
- [16] Tyler MJ: Australian frogs. Penguin Books Australia Ltd., 1989.
- [17] Vershinin VL: Ecological specificity and microevolution in amphibian populations in urbanized areas. Ecological specificity of amphibian populations. Advances in amphibian research in the former Soviet Union. Volume 7. Pensoft Publishers. Moscow-Sophia, 2002: 1-161.
- [18] Henle K, Dubois A, & Vershinin V: A review of anomalies in natural populations of amphibians and their potential causes. Mertensiella. 2017a. 25: 57-164.
- [19] Vershinin V. L., Berzin D. L., Vershinina S. D. Amphibian teratology – possible adaptive and evolutionary interpretations. Bulletin of St. Petersburg State University. Ser. 3. Biology. 2016. 3: 36-40 [in Russian].
- [20] Turing AM: The Chemical Basis of Morphogenesis. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences. (237), 641: 37-72.
- [21] Simirsky VN, Duncan MK: The integrines role in stabilisation and modulation of epithelium differentiation on example of eye lens. Abstracts of the conference "Morphogenesis in individual and historical development: sustainability and variability", 21-23<sup>rd</sup> of Aprile 2015. Moscow, 2015: 62-63. [in Russian].
- [22] Specchia V, Piacentini L, Tritto P, Fanti L, D'Alessandro R, Palumbo G, Pimpinelli S, Bozzetti MP: Hsp90 prevents phenotypic variation by suppressing the mutagenic activity of transposons. Nature. Advance online publication 10 January 2010. Doi:10.1038/nature08739
- [23] Vershinin VL and Neustroeva NS: The Role of Trematode Infestation in the Specifics of Skeleton Morphogenesis of *Rana arvalis* Nilsson, 1842. Doklady Biological Sciences. 2011. (440), 1: 290-292.